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Zr_2Fe TRITIUM SCAVENGER BEDS

Report No. 89-199-K

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ABSTRACT

Tritium handling systems housed within secondary enclosures usually impose a chronic and an acute tritium load on the secondary environment. This tritiated atmosphere requires a tritium scavenging treatment in order to ensure safe working conditions and to minimise tritium emissions to the outside environment. One viable and attractive option is to utilise a regenerable metal getter, zirconium-iron alloy Zr_2Fe, to scavenge the tritium directly from the secondary atmosphere.

This report documents the key aspects of 800 g and 5 kg zirconium-iron tritium scavenger beds designed and fabricated for service in the Tritium Laboratory at Ontario Hydro Research Division. A brief description of the tritium scavenger beds along with a short account of their operating characteristics are presented.

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EXECUTIVE SUMMARY

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Experimental or process systems handling significant quantities of tritium are usually enclosed in gloveboxes containing an inert atmosphere. During the course of routine and off-normal operations the secondary enclosure is usually subject to chronic and acute tritium releases, respectively. The tritiated secondary environment, which is usually displaced by incoming tritium-free inert gas, requires detritiation to a sufficiently low-level prior to venting it to the outside environment or returning it to the glovebox. Traditionally this is accomplished by catalytic oxidation of the tritium followed by sorption of tritiated water onto molecular sieves. An attractive alternative is to use regenerable metal getters to directly scavenge the tritium from the secondary environment. In this report we present the salient aspects of the singly-contained 800 g and 5 kg zirconium-iron (Zr_2Fe) scavenger beds (also known as tritium removal beds), designed and fabricated for service in the Tritium Laboratory at the Research Division of Ontario Hydro. The report describes the bed design, examines the flow impedance due to the usage of filters, presents the total bed flow impedance measured, considers the bed power requirements, and discusses the operating characteristics of the Zr-Fe alloy.

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To Dr. D. Mills
Director of Research

Zr_2Fe TRITIUM SCAVENGER BEDS

1.0 INTRODUCTION

The environment of secondary enclosures housing tritium handling systems usually suffer from chronic and acute or abnormal tritium releases. To ensure safe working conditions and minimum tritium emissions to the outside environment, the secondary atmosphere needs periodic or continuous tritium scavenging treatment. Conventionally this is accomplished by catalytic oxidation and sorption of tritiated water on molecular sieves. An attractive alternative is to use a regenerable metal getter to directly scavenge the tritium from the secondary atmosphere. Experiments examining the tritium removal efficiency of a particular metal getter, zirconium-iron alloy Zr_2Fe, have been carried out and the results demonstrate the viability of this getter material for tritium scavenging/1,2/.

The objective of this report is to document the key aspects of 800 g and 5 kg zirconium-iron tritium scavenger beds, also referred to as tritium removal beds, designed and fabricated for service in the Tritium Laboratory at Ontario Hydro Research Division (OHRD). In the following sections a brief description of the tritium scavenger beds along with a short account of their operating characteristics, both bed design and getter material dependent, are presented.

2.0 DESCRIPTION

The form of the Zr_2Fe getter alloy used in the fabrication of the tritium scavenger beds is 6 mm diameter by 4 mm long pellets (or pills). The pills are formed out of Zr_2Fe powder with a grain size ranging from 0 - 220 μm,

resulting in pellets with a void fraction of 40 - 50% compared to the ingot of the alloy. The advantage of using the pill form of the alloy is that it has approximately 90% of the surface area of the powder and yet it is easy to handle. The properties of the zirconium-iron alloy are summarised in Table 1.

2.1 800 g Tritium Scavenger Bed

A schematic of the 800 g tritium scavenger bed is shown in Figures 1a and 1b, where the latter gives the key bed dimensions. The getter alloy is contained within the annular space of two concentric sintered stainless steel cylinders. A cable heater which is coiled around the outer sintered cylinder serves to heat the getter material and heat the incoming gas during a tritium removal operation. The incoming gas first diffuses through the outer sintered cylinder, followed by the getter material, and then leaves via the inner sintered cylinder. Thermocouples are imbedded within the annular region to provide the temperature of the zirconium alloy. The particulars of the materials used in the fabrication of the tritium removal bed are summarised in Table 2.

2.2 5 kg Tritium Scavenger Bed

The 5 kg tritium scavenger bed schematic and drawing with dimensions are shown in Figures 2a and 2b, respectively. The construction of the 5 kg bed is similar to the 800 g bed with the exceptions of sintered cylinders of a larger particulate rating and a thicker outer sintered cylinder; two coiled cable heaters, one of which serves as a back-up heater; and an extra thermocouple. The particulars of the materials used in the fabrication of the scavenger bed are given in Table 3.

3.0 OPERATING CHARACTERISTICS

There are principally two modes in which the scavenger beds are operated: tritium scavenging and tritium regeneration or recovery. The bed design dependent concerns that arise when operating the removal bed in either of the above modes are: flow impedance and heat transfer. Other operating

characteristics of interest, which are getter material dependent, are: activation procedure prior to carrying out a scavenging operation; the optimum tritium removal and regeneration temperatures; and, tritium removal efficiency and the influence of impurities on the latter. The above operating aspects, with respect to the two scavenging beds, are discussed in the following sub-sections.

3.1 Flow Impedance

Given the design of the scavenger beds it is assumed that the sintered tubes offer the greatest flow impedance or, alternatively, are the principle conductance limiting flow elements. The conductances of stainless steel sintered porous filters, used in the fabrication of these beds, have been measured/3/. Even though conductances vary not only from filter production batch to batch but indeed from filter to filter, the measurements can be used to determine approximate conductance values. The semi-empirical representation of the conductance measurements is given in Table 4; relevant fluid properties are given in Table 5.

Typical pressures and flow rates during the scavenging mode are 1 atmosphere and a few standard L/min to a few L/s, respectively. In view of these operating conditions it is evident that the viscous term ($f_v P_a$) is much greater than the molecular term (γf_m) in the conductance equation given in Table 4. Therefore, the conductance equation can be reduced to the following form:

$$F = f_v P_a \frac{A}{\ell}$$

$$= f_v \frac{(P_1 + P_2)}{2} \frac{A}{\ell} \quad .$$

The product of conductance, F, and the pressure drop, ΔP, gives the flow rate, Q [torr L/s]:

$$Q = F\,\Delta P$$

$$= f_v \frac{(P_1^2 - P_2^2)}{2} \frac{A}{\ell} .$$

Defining the downstream pressure in terms of the upstream pressure $P_2=(1-\epsilon)P_1$, where ϵ is the fractional change in pressure across the filter, and introducing a normalised flow area, $\alpha = A\ (2Q\ell/f_v P_1^2)^{-1}$, then the above flow equation can be simply expressed as

$$\alpha = \frac{1}{\epsilon\ (2 - \epsilon)}, \quad 0 < \epsilon < 1 .$$

The foregoing expression, a convenient representation of the normalised flow area in terms of the fractional pressure change, is graphically illustrated in Figure 3. It is seen that as the fractional pressure change ϵ tends to zero, the normalised area α tends to infinity. On the other hand as ϵ tends to unity, α tends to unity. The above expression can also be written so that ϵ is given as a function of α:

$$\epsilon = 1 - (1 - \alpha^{-1})^{1/2}, \quad 1 < \alpha < \infty .$$

Implicit in the preceding development is that the upstream pressure is known and therefore the downstream pressure can be defined by introducing the fractional pressure change term ϵ. An alternative and experimentally more useful expression is obtained when the downstream pressure is known and the upstream pressure is defined as $P_1 = (1 + \tilde{\epsilon}\ )P_2$, where $\tilde{\epsilon}$ is the fractional change in pressure across the filter with respect to the downstream pressure. Introducing the normalised flow area $\tilde{\alpha} = (2Q\ell/f_v P_2^2)^{-1}$, then the flow equation becomes:

$$\tilde{\alpha} = \frac{1}{\tilde{\epsilon}\ (2 + \tilde{\epsilon})}, \quad 0 < \tilde{\epsilon} \quad \infty .$$

In this expression the fractional change in pressure $\tilde{\epsilon}$ tends to zero as the normalised area $\tilde{\alpha}$ tends to infinity, and conversely the normalised area tends to zero as the fractional pressure change tends to infinity. For completeness, the inverse of the preceding expression is:

$$\tilde{\epsilon} = -1 + (1 + \tilde{\alpha}^{-1})^{1/2} , \quad 0 < \tilde{\alpha} < \infty.$$

In evaluating the pressure drop across the scavenger bed it is assumed that all of it occurs across the sintered cylinders; in actual fact there are other factors that contribute to the total pressure drop. The pressure drop across the inner sintered cylinder is computed by evaluating the normalised area $\tilde{\alpha}_i$ for a given pressure P on the downstream side of the inner cylinder flow rate Q, inner sintered cylinder dimensions, and fluid dependent reduced viscous conductance; the above normalised area is then used to compute $\tilde{\epsilon}_i$ and thereby the pressure upstream of the inner cylinder but downstream of the outer cylinder is determined. This pressure is then used to compute $\tilde{\alpha}_o$, normalised area for the outer cylinder, which in turn is used to determine $\tilde{\epsilon}_o$, and thus obtain the total pressure drop across both of the sintered cylinders:

$$\begin{aligned} \Delta P_{total} &= \Delta P_i + \Delta P_o \\ &= \tilde{\epsilon}_i P + \tilde{\epsilon}_o (P + \tilde{\epsilon}_i P) \\ &= (\tilde{\epsilon}_i + \tilde{\epsilon}_o)P + \tilde{\epsilon}_o\tilde{\epsilon}_i P . \end{aligned}$$

The computed and measured pressure changes as a function of the flow rate of helium through the 800 g scavenger bed are shown in Figure 4. Similar data due to helium and argon flow through the 5 kg bed are given in Figures 5 and 6, respectively. The experimental measurements were carried out at a room temperature of 20°C. In all cases it is seen that the measured pressure drop is larger than that computed and that the difference in the pressure drop increases with increasing flow rate. In fact the measured pressure change is seen to observe the following non-linear dependence on Q: $Q^{1.5}$ and $Q^{1.6}$ for the 800 g and 5 kg beds, respectively. The larger measured pressure drop clearly indicates that the calculation has not accounted for other impedance contributing elements: the getter pellets, reduced filter flow area due to coiling of heater(s) around the outer sintered cylinder, and isolation valves. Since it is known that the actual loss in flow area due to heater coverage is small, as the contact is mainly point-wise, and that the pressure drop across the Nupro valves is comparatively negligible, the above observation suggests that as the flow increases the pressure drop across the getter material becomes significant.

3.2 Power Requirements

Tritium scavenger bed power requirements are determined on the basis of the operating conditions: during the scavenger mode the getter material is usually maintained at 350°C with a tritium bearing inert (or N_2) gas stream, for instance helium, typically flowing at 1 L/s; and, during regeneration the getter is typically held at 700°C in a slow moving inert gas stream or in vacuum. Given the above operating conditions the minimum power required for heating the getter material and the incoming helium stream, and conductive and convective power losses are estimated in the following. The data are summarised in Table 6.

The power required P [W] to raise the getter material to a certain temperature T [K], from an initial temperature T_a [K], can be estimated from the following relation:

$$P = \frac{Q}{\Delta t} = \frac{\Sigma\, c_p\, m\, \Delta T}{\Delta t}$$

where Q [J] is the total energy required, defined as the sum of the product of the specific heat c_p [J/g/K] of each material, its mass m [g] and the temperature difference $\Delta T = T - T_a$, and Δt [s] is the time available to reach the desired temperature T. In this estimate it is assumed that there is no loss of heat. The estimated power requirements to raise the 800 g scavenger bed to 350°C and 700°C, from an initial temperature of 20°C, over a period of 30 min and 60 min, respectively, are 126 W and 130 W; similar calculations for the 5 kg bed yield power requirements of 523 W and 539 W. The foregoing data are obtained by assuming that only the getter material, sintered cylinders and end caps are raised to the said temperature and that the density of the sintered cylinders is that of solid stainless steel.

The power required to raise the incoming inert stream from T_a to T can be estimated using the following relation:

$$P = q\, \rho\, c_p\, \Delta T$$

where q [m^3/s] is the volumetric gas flow rate at standard pressure and ambient temperature T_a, ρ [kg/m^3] is the gas density and c_p [J/kg/K] is the specific heat of the gas. The power required to raise the temperature of a helium stream, flowing at 1 L/s, from 20°C to 350°C is 285 W. This power requirement is clearly independent of the bed size. The above estimates were obtained using the helium gas properties at standard pressure and ambient temperature T_a of 20°C.

The conductive power loss during operation is principally via the outlet tube which supports the getter assembly proper. Assuming that the end of the tube supporting the getter assembly is at temperature T and the other end that is welded to the outer shell is at temperature T_a such that the distance between the two ends is ℓ and that the temperature gradient is linear, then the rate of heat loss is given by:

$$P = A\,k\,\frac{(T - T_a)}{\ell}$$

where k [J/s/cm/K] is the thermal conductivity and A [cm^2] is the cross-sectional area of the outlet tube. The conductive power losses from the two beds during the scavenging and regeneration modes of operation are 15 W and 31 W respectively for the 800 g bed, and 14 W and 30 W respectively for the 5 kg bed. These estimates are obtained using an ℓ value of 0.75 in (1.9 cm) and 1.0 in (2.5 cm) for the 800 g and 5 kg scavenger beds, respectively.

During the scavenging and regeneration (using an inert gas) modes of operation there will be some convective power loss from the scavenging bed. Assuming that helium is used in the two operation modes, then a simple way of obtaining a conservative estimate of this rate of heat loss is to assume the following: the outer sintered cylinder is at temperature T; the inside of the vacuum wall is at T_a; the interspace between the outer sintered cylinder and the vacuum wall contains "stagnant" helium which serves to transmit the power loss; the principal source of convective power loss is along the length of the outer sintered cylinder; and, a parallel plate representation is valid. Then, the power loss is given by the following relation/4/:

$$P = A\ Nu\ k \frac{\Delta T}{\delta}$$

where A [cm^2] is the geometric area of the outside of the outer sintered cylinder, k [W/cm/K] is the thermal conductivity of helium, $\Delta T = T - T_a$, δ is the distance between the outside of the outer sintered cylinder and the inside of the vacuum wall, and $Nu = 0.068\ Gr^{1/3}$ (for $Gr < 4x10^5$) is the Nusselt number. The Grashof number Gr is given by the expression:

$$Gr = \frac{\rho^2\ g\ \beta\ (T - T_a)\ \delta^3}{\mu^2}$$

where ρ [g/cm^3] is the helium density, $g = 981\ cm/s^2$, $\beta = 1/T_a$, and μ [poise] is the viscosity of helium. For the bed temperature T of 350°C, ambient temperature T_a of 20°C and helium properties (k, ρ and μ) evaluated at 200°C, we obtain estimates of the convective power losses of 56 W and 181 W for the 800 g and 5 kg beds, respectively. The power losses for bed temperature T of 700°C are 147 W and 473 W for the 800 g and 5 kg beds, respectively. These estimates were also obtained using helium properties at 200°C.

From the foregoing estimated data it is evident that the power capacities of the heaters on the 800 g and 5 kg beds, respectively, are adequate for carrying out scavenging and regeneration operations at typical operating conditions of 350°C bed temperature with a helium flow of 1 L/s and bed temperature of 700°C in vacuum or helium, respectively. The above data also shows that the convective power losses during either the scavenging or regeneration operating modes is significant and therefore the beds should be appropriately insulated to minimise the losses.

It is noteworthy that the heaters used in these beds are only rated for a maximum continuous operating sheath temperature of 650°C. This upper limit principally arises out of the rather high watt densities of the heaters. The situation is further aggravated by the lack of intimate contact between the surfaces of the heating elements and the conducting media. In view of this and the fact that during operation the heater sheath temperature is not monitored, it is important that when carrying out a recovery operation the rate of temperature rise is slow, the bed is well insulated and that the

regeneration is in the presence of helium at standard pressure and not under vacuum.

3.3 Zirconium-Iron Alloy Operating Characteristics

A prerequisite to the operation of a Zr_2Fe tritium scavenger bed is activation of the zirconium-iron alloy, that is, displacment of the oxide layer resulting in the exposure of adsorption sites. The zirconium-iron alloy bed is easily activated by baking it at $\geq$ 500°C in high vacuum or in the presence of a stream of ultra high purity noble gas for a duration of a couple hours. Alternatively, the getter can be activated by maintaining it at the lower mean operating temperature of 350°C for a period of several hours.

The Zr_2Fe getter is highly reactive with the hydrogen isotopes and water at typical operating temperatures of 300 - 400°C. The zirconium-iron alloy, which is to a large extent chemically non-reactive with nitrogen up to approximately 450°C, can be used for detritiation of nitrogen gas in addition to the noble gases. The getter is also highly reactive with O_2, CO and NH_3 at the above operating temperatures; methane is also removed at these temperatures albeit at a very slow rate. Trace levels of the above impurities do not passify the getter surface and therefore tritium removal in their presence is not significantly affected/1,2/. The zirconium alloy reacts irreversibly with the impurities oxygen and carbon, however the reaction with hydrogen is reversible. In particular, sorbed hydrogen isotopes can be recovered from the alloy by raising its temperature to about 700°C.

The 800 g and 5 kg Zr_2Fe tritium scavenger beds have not been systematically characterised with respect to their tritium removal efficiencies. However, from experimental results reported in reference 1 it is clear that these beds can detritate a gas stream from a few Ci/m^3 down to $\mu Ci/m^3$ level in a few passes, where the number of passes decreases with increasing residence time of the tritium bearing stream in the getter bed. Furthermore, from the data reported in reference 5 it is known that the 5 kg bed operating at a mean temperature of 350°C has a minimum purification factor (PF) of 19 400 on a 0.6 L/s helium stream; purification factor is defined as the ratio of the inlet to outlet tritium concentrations. A PF of 25 000 was measured for a lower inlet concentration of about 5 Ci/m^3. It is noteworthy that the above data is for elemental tritium. Experiments explicitly

examining the removal efficiency of tritium oxide have not been carried out, however, there is no evidence that the getter does not remove tritiated water. The foregoing operating characteristics are summarised in Table 7.

4.0 SUMMARY

This report documents the key features of the 800 g and 5 kg Zr_2Fe tritium scavenger beds designed for service in the Ontario Hydro Research Division Tritium Laboratory. From the foregoing presentation it is evident that the following features need to be included in the fabrication of tritium scavenger beds in the future:

1. heaters rated to operate at a minimum temperature of 700°C,
2. intimate thermal contact between the entire surface of the heating element and the conductive medium to be heated,
3. thermocouple monitoring the heater temperature,
4. secondary containment, and
5. minimisation of convective heat loss.

In addition to the above, the scavenger beds need to be systematically characterised with respect to tritium (elemental and oxide forms) removal efficiency at a variety of conditions including different inlet tritium concentration, flow rate and bed capacity.

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TABLE 1

PROPERTIES OF Zr_2Fe GETTER ALLOY

Composition (Wt %)	76.6 Zr 23.4 Fe
Bulk Density (g/cm^3)	6.9
Pellet Density* (g/cm^3)	~5
Pellet Filling Density** (g/cm^3)	~3.2
Melting Point (°C)	950 - 1100
Burning Temperature in Air (°C)	400
Powder Grain Size* (μm)	0 - 220
Equilibrium Pressure - Composition - Temperature (P in Torr) (q in Torr L/g) (T in K)	$\log_{10} P = 5.03 + 2 \log_{10} q \frac{-6220}{T}$

* Defined as the ratio of the mass of a 6 mm ø X 4mm pellet to its volume; measured at OHRD.

** Defined as the ratio of the mass of the pellets to the volume occupied. This definition assumes that the pellets are not systematically stacked in the volume but rather occupy it at random. Measurement obtained at OHRD.

TABLE 2

800 g TRITIUM SCAVENGER BED MATERIALS

ITEM	PARTICULARS
Metal Getter	Zr_2Fe (ST-198 Alloy) Pills 6 mm ø X 4 mm 780 g Manufacturer: SAES Getters, S.p.A., Milano 20151, Italy
Sintered Tubes	316L Stainless Steel 5 μm Grade Filter 0.0625" (1.59 mm) Thickness Manufacturer: Mott Metallurgical Corporation Farmington, Connecticut 06032, USA
Heater	Coiled Cable Heater Stainless Steel Sheath Magnesium Oxide Insulation Maximum Continuous Operating Sheath Temperature*: 650°C 3" (76 mm) I.D. X 3.75" (95 mm) X 0.125" (3.18 mm) 240 V, 1000 W, 28 W/in^2 (4.3 W/cm^2) Code No. 125CH93A1X, Option 2C Supplier: ZESTA Engineering, Toronto, Ontario
Thermocouples	Type K Inconel 600 Sheath 0.0625" (1.59 mm) ø
Valves	Stainless Steel, Metal Bellows Part No. SS-8BG-TW Manufacturer: NUPRO Company, Willoughby, Ohio 44094, USA
End Caps, Outer Shell	304L/316L Stainless Steel

* Stipulated by supplier

TABLE 3

5 kg TRITIUM SCAVENGER BED MATERIALS

ITEM	PARTICULARS
Metal Getter	Zr_2Fe (ST-198 Alloy) Pills 6 mm ø X 4 mm 5 kg Manufacturer: SAES Getters, S.p.A., Milano 20151, Italy
Sintered Tubes	316L Stainless Steel 20 µm Grade Filter 0.0625" (1.59 mm) Thickness [Internal Cylinder] 0.125" (3.18 mm) Thickness [External Cylinder] Manufacturer: Mott Metallurgical Corporation Farmington, Connecticut 06032, USA
Heater	Coiled Cable Heater Stainless Steel Sheath Magnesium Oxide Insulation Maximum Continuous Operating Sheath Temperature*: 650°C 5" (127 mm) I.D. X 1.5" (38 mm) X 0.125" (3.18 mm) 120 V, 1052 W, 16.8 W/in^2 (2.6 W/cm^2) 161" (4 m) Long, 4" (102 mm) Cold Length, Option 2C Supplier: ZESTA Engineering, Toronto, Ontario
Thermocouples	Type K Inconel 600 Sheath 0.125" (3.18 mm) ø
Valves	Stainless Steel, Metal Bellows Part No. SS-8BG-TW Manufacturer: NUPRO Company, Willoughby, Ohio 44094, USA
End Caps, Outer Shell	304L/316L Stainless Steel

* Stipulated by supplier

TABLE 4

CONDUCTANCES OF SINTERED STAINLESS STEEL POROUS FILTERS*

$$F = (f_v P_a + \gamma f_m) \frac{A}{L}$$

$f_v = C\alpha$

$f_m = D\beta$

$P_a = (P_1 + P_2)/2$

$C = 0.5236\ \eta^{-1}$

$D = 30.48\ \sqrt{T/M}$

F : Flow Conductance [L s^{-1}]

f_v : Reduced Viscous Conductance [L $s^{-1} cm^{-1}$ $torr^{-1}$]

f_m : Reduced Molecular Conductance [L s^{-1} cm^{-1}]

P_a : Average Pressure Across the Filter [torr]

C,D : Fluid Dependent Properties at Prevailing Temperature

α, β : Semi-empirical Filter Geometric Parameters

P_1 : Upstream Pressure [torr]

P_2 : Downstream Pressure [torr]

η : Gas Viscosity at Prevailing Temperature [P, poise]

M : Gas Molecular Weight [g/mole]

T : Prevailing Temperature [K]

A : Filter Flow Surface Area [cm^2]

L : Filter Thickness [cm]

γ : Flow Regime Dependent Parameter [1]

Pure Molecular Flow: $\gamma = 1$
Pure Viscous Flow: $\gamma = 0.81$
Intermediate Flow Regime: $0.81 < \gamma < 1$

Semi-empirical Filter Geometric Parameters

Filtration Grade [μm]	α [cm^2]	β [cm]
0.5	6.34×10^{-9}	2.49×10^{-5}
2	2.46×10^{-8}	5.12×10^{-5}
5	4.35×10^{-8}	6.53×10^{-5}
10	1.14×10^{-7}	1.40×10^{-4}
20	2.23×10^{-7}	2.58×10^{-4}

* Manufactured By Mott Metallurgical Corporation

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TABLE 5

FLUID PROPERTIES OF INTEREST

FLUID	VISCOSITY, η [T = 20°C] [μ poise]	MOLECULAR WEIGHT, M [g/mole]
Dry Air	183.4	28.964
He	194.1	4.0026
Ar	221.7	39.948
N_2	174.8	28.0134
H_2	87.5	2.0157
D_2	123.7*	4.0282
T_2	151.4*	6.0321

* The viscosity of D_2 and T_2 were computed on the basis that the viscosities are approximately in the same ratio as the square roots of the molecular masses, which has been experimentally verified for molecules having approximately equal diameters.

TABLE 6

ESTIMATED TRITIUM SCAVENGER BED POWER REQUIREMENTS

DESCRIPTION	800 g BED POWER REQUIREMENT [W]	5 kg BED POWER REQUIREMENT [W]
Heating Getter from 20°C to 350°C in 30 min	126[a]	523[b]
Heating Getter from 20°C to 700°C in 60 min	130[a]	539[b]
Heating 1 L/s He Stream from 20°C to 350°C	285[c]	285[c]
Conductive Heat Loss at 350°C	15[d,e]	14[d,f]
Conductive Heat Loss at 700°C	31[d,e]	30[d,f]
Convective Heat Loss at 350°C	56[g,h]	181[g,i]
Convective Heat Loss at 700°C	147[g,h]	473[g,i]

a Estimated mass of stainless steel (S.S.) = 880 g; $c_p^{20°C}$ (S.S.) = 0.5 J/g/K; estimated $c_p^{20°C}$ (Zr_2Fe) = 0.32 J/g/K

b Estimated mass of S.S. = 2 510 g

c $\rho^{20°C}$ (He) = 0.17 kg/m^3; $c_p^{20°C}$ (He) = 5.2 X 10^3 J/kg/K

d $k^{200°C}$ (S.S.) = 0.17 W/cm/K

e = 1.9 cm

f = 2.5 cm

g $\rho^{200°C}$ (He) = 1.0 X 10^{-4} g/cm^3; $\mu^{200°C}$ (He) = 2.67 X 10^{-4} g/cm/s; $k^{200°C}$ (He) = 0.002 W/cm/K

h δ = 1.3 cm

i δ = 1.1 cm

TABLE 7

Zr_2Fe ALLOY OPERATING CHARACTERISTICS

Activation	1. At $\geq$ 500°C in vacuum or ultra high purity noble gas stream for 1 hr, or 2. At the mean operating temperature of 350°C for several hours
Scavenging Temperature	300 - 400°C
Regeneration Temperature	700°C
Chemically Inert Gases Up to ~450°C	N_2, noble gases
Chemically Reactive Gases at 300 - 400°C	Hydrogen isotopes, water, O_2, CO, NH_3, CH_4 (slow rate of reaction)
Tritium Removal Efficiency	Detritiation of a gas stream from a few Ci/m^3 to μ Ci/m^3 in a few passes*

* See section 3.3 for details

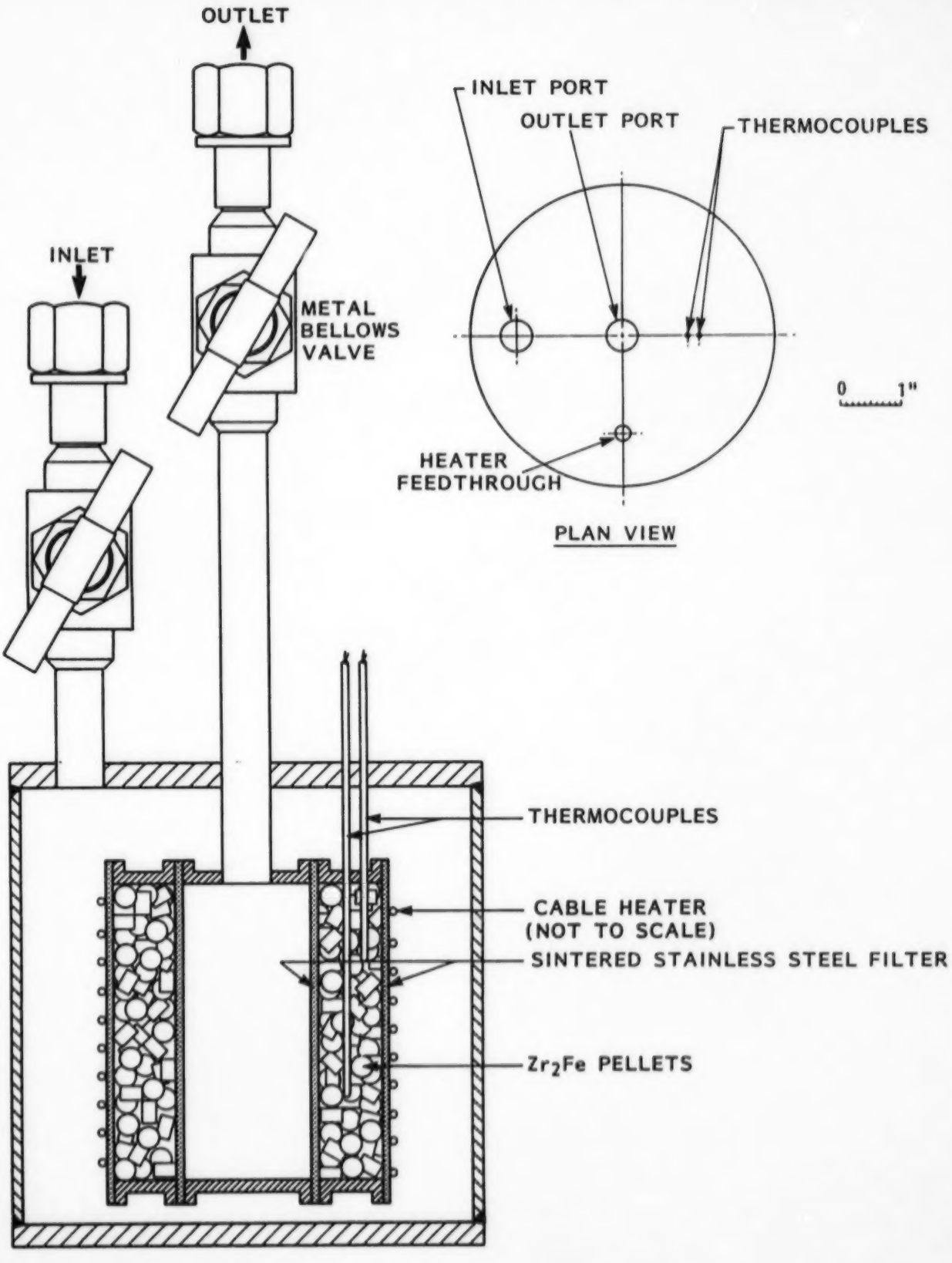
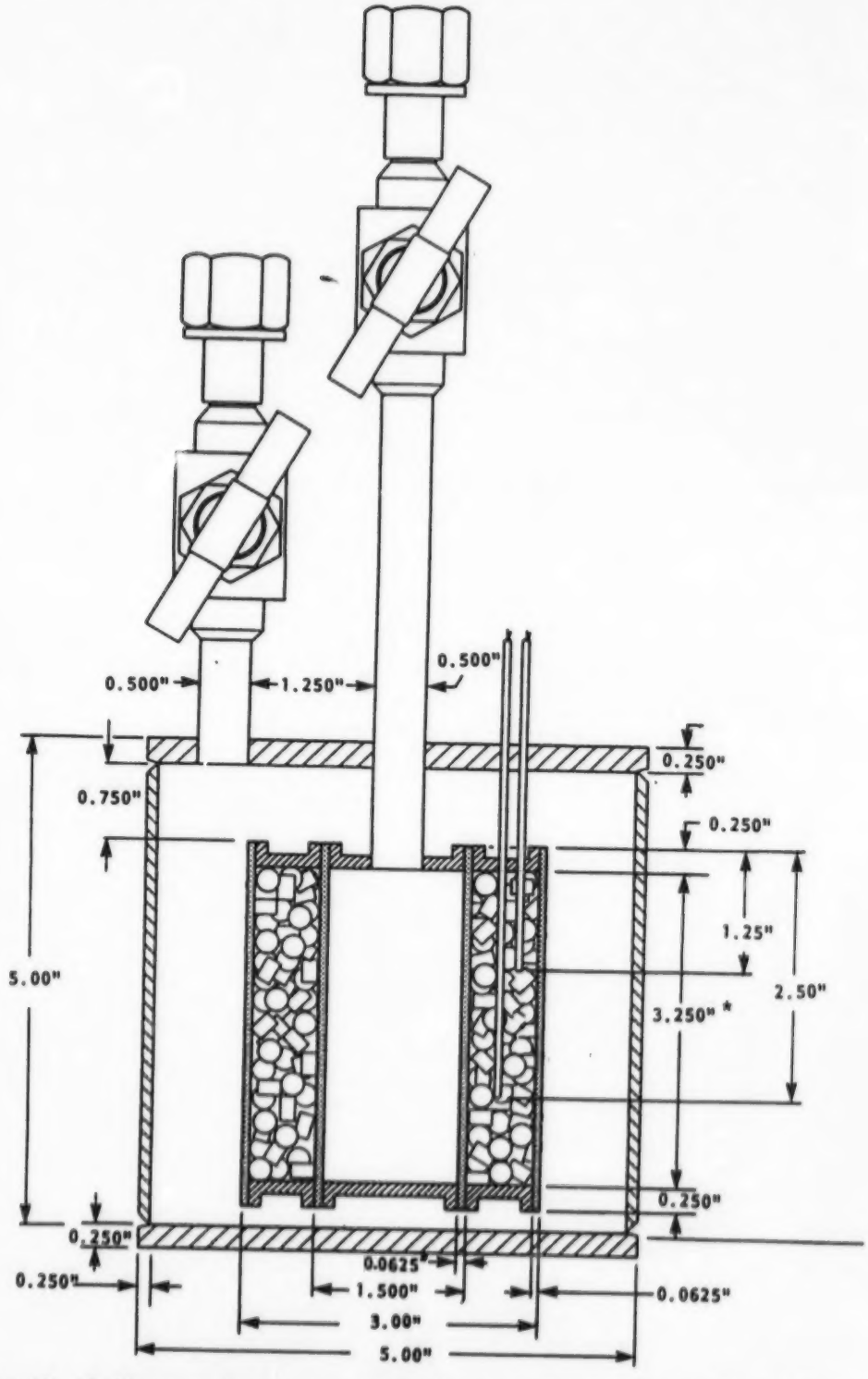


FIGURE 1a
800g Zr_2Fe TRITIUM SCAVENGER BED

174752-RD



* Length of filter cylinder available for flow is 3.125" since 0.125" spacers (not shown) were inserted in the bottom of the bed prior to welding the end caps.

FIGURE 1b

800 g Zr_2Fe TRITIUM SCAVENGER BED WITH DIMENSIONS

176748-RD

89-199

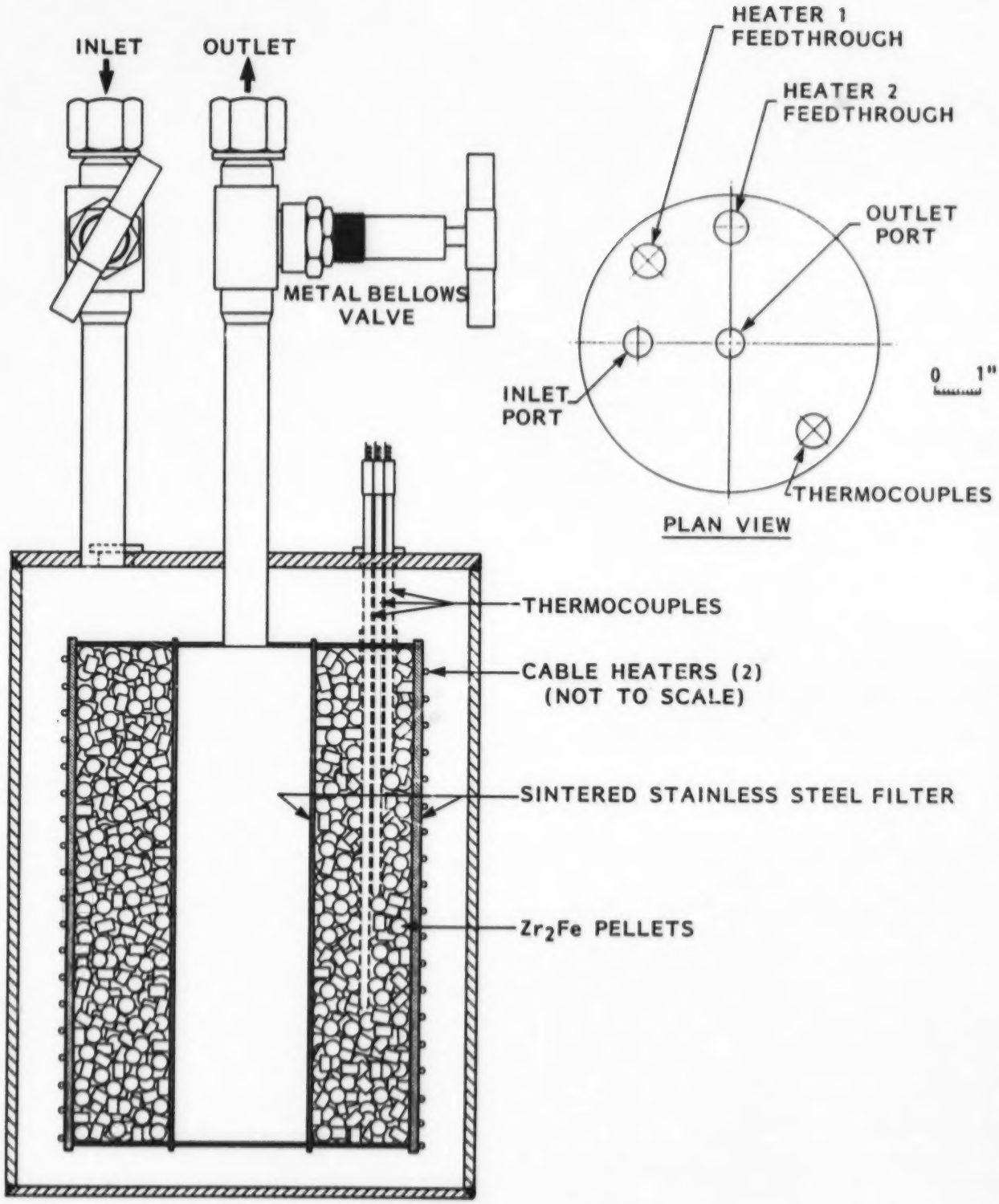
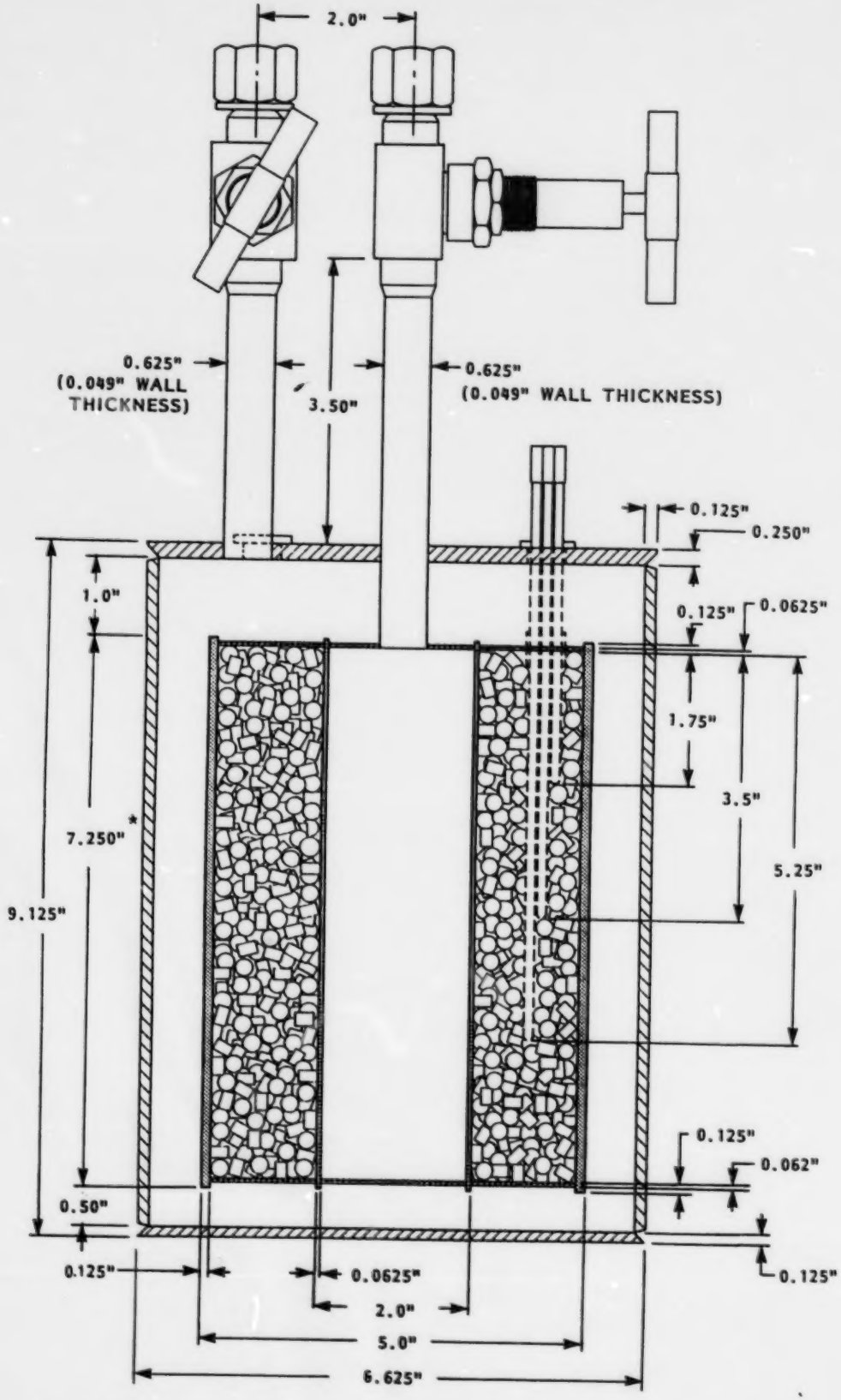


FIGURE 2a

5kg Zr_2Fe TRITIUM SCAVENGER BED



* Length of filter cylinder available for flow is 6.875" since 0.125" spacers (not shown) were inserted in the bottom of the bed prior to welding the end caps.

FIGURE 2b

5 kg Zr_2Fe TRITIUM SCAVENGER BED WITH DIMENSIONS

176749-RD

89-199

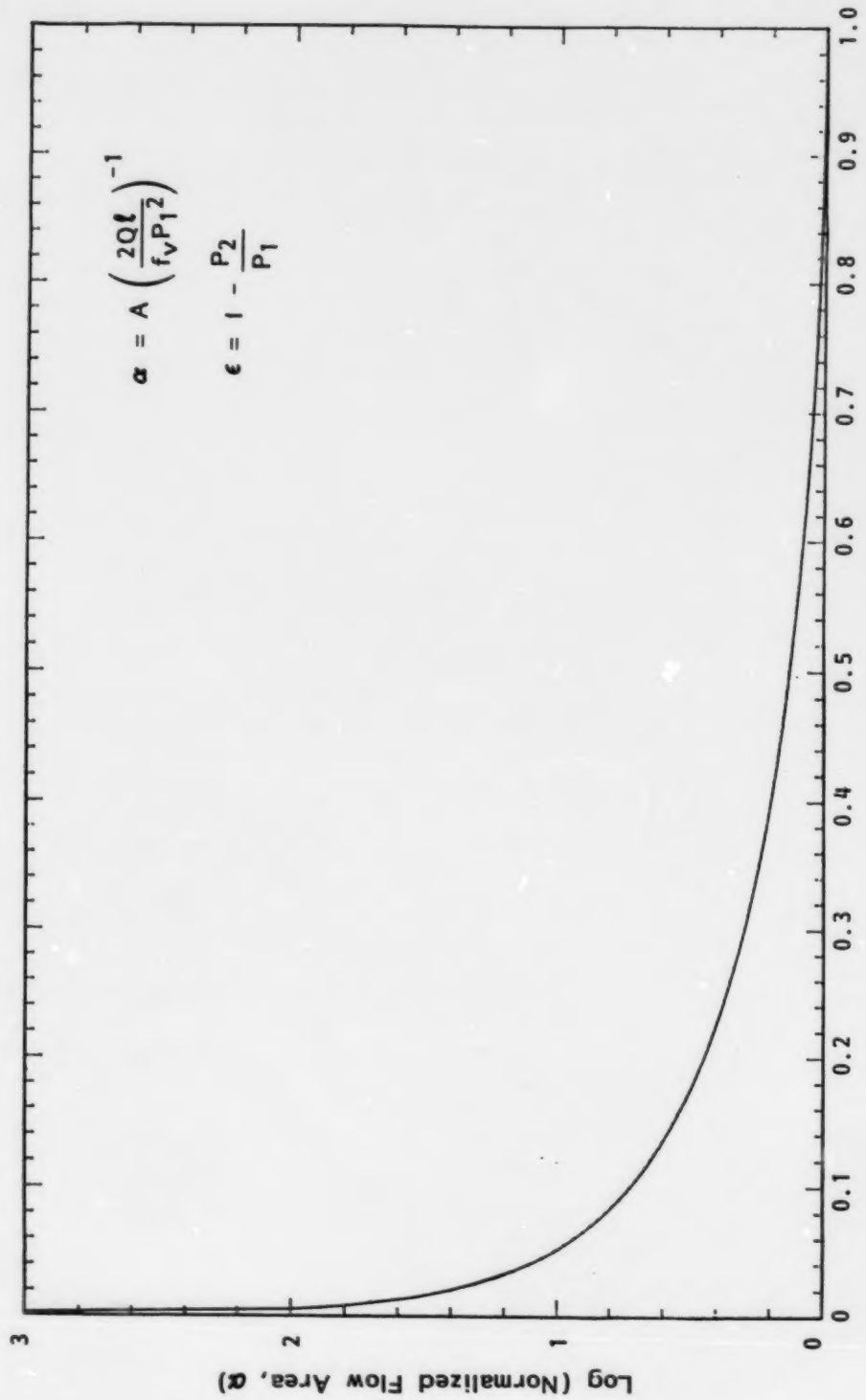


FIGURE 3
DEPENDENCE OF NORMALIZED FLOW AREA ON FRACTIONAL PRESSURE CHANGE

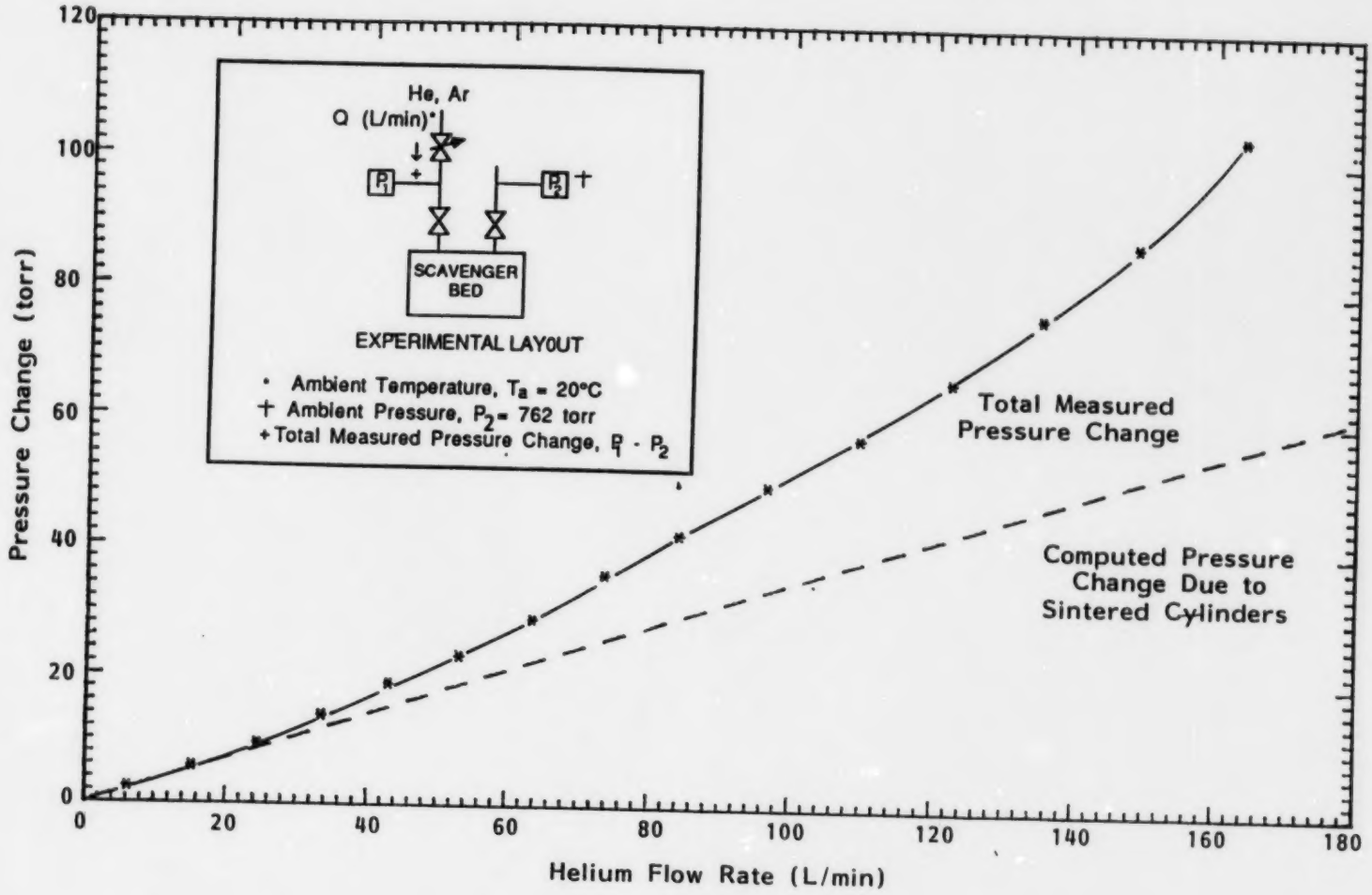


FIGURE 4
PRESSURE CHANGE ACROSS AN 800 g TRITIUM SCAVENGER BED

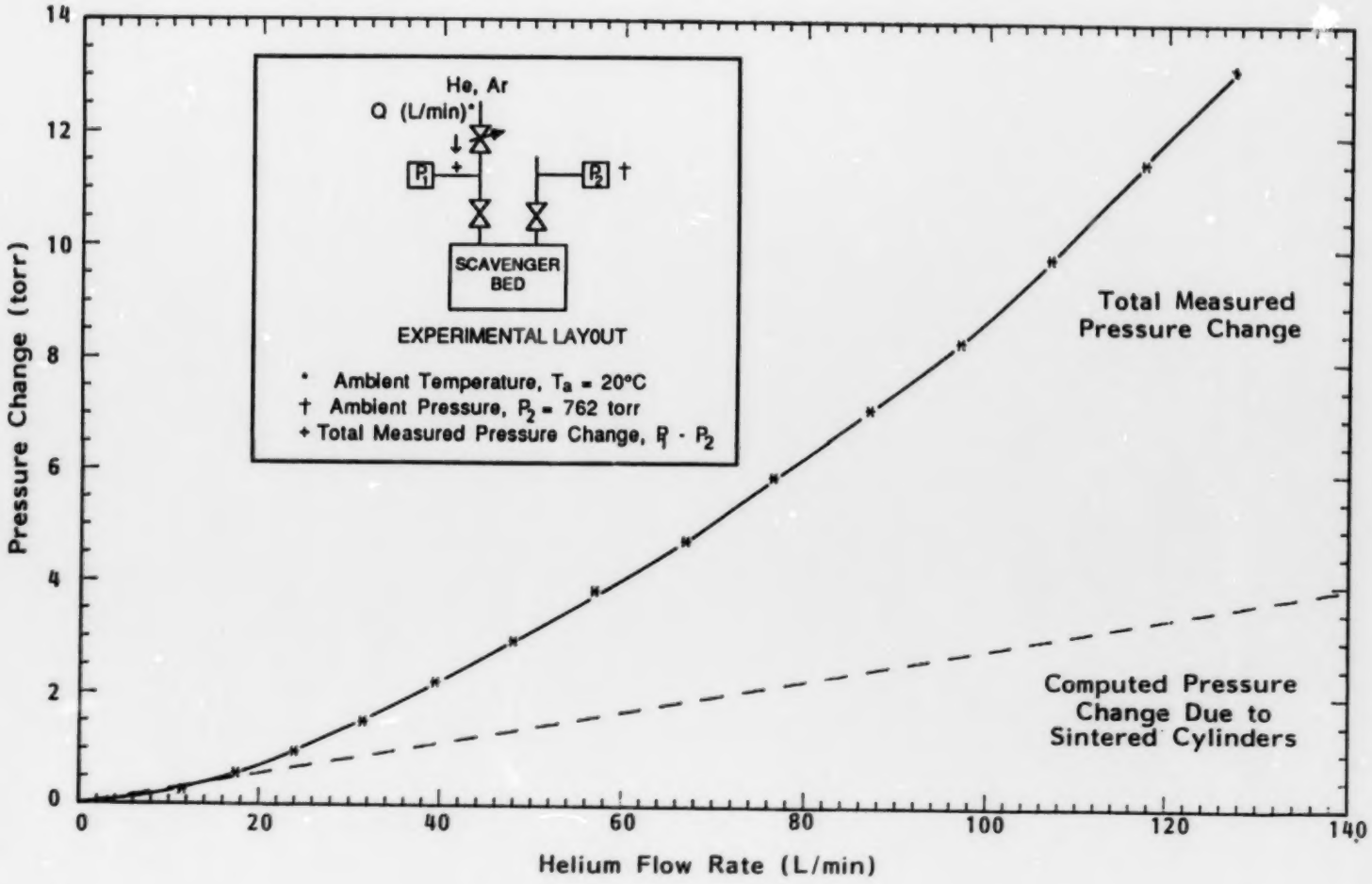


FIGURE 5
PRESSURE CHANGE ACROSS A 5 kg TRITIUM SCAVENGER BED

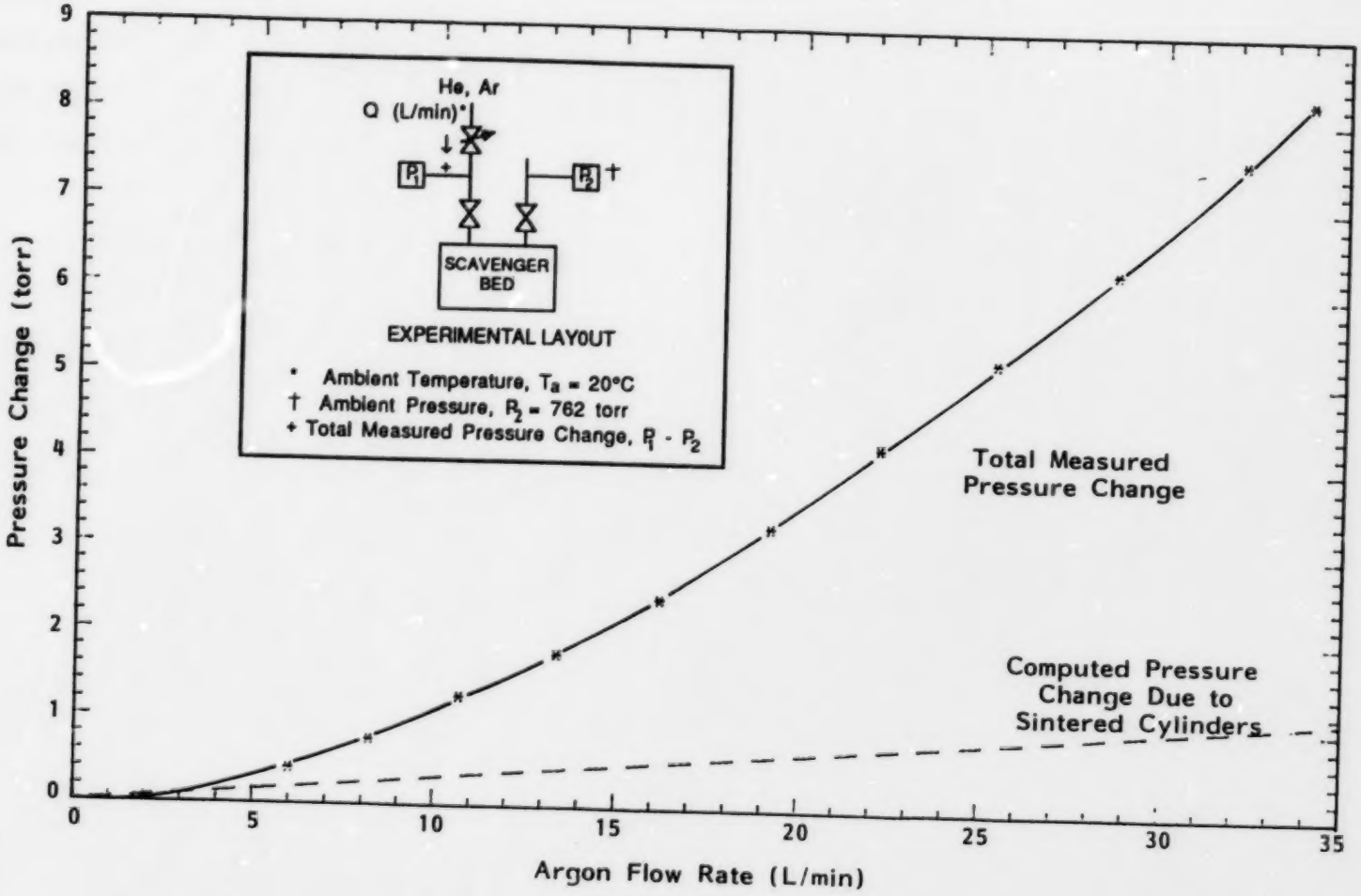


FIGURE 6
PRESSURE CHANGE ACROSS A 5 kg TRITIUM SCAVENGER BED

89-199 176879-RD